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REVIEW ARTICLE

Surgical treatment for young adult hip dysplasia: joint-preserving options

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Abstract Developmental dysplasia of the hip (DDH) is a spectrum of disorders that results in anatomic abnormalities leading to increased contact stress in the joint and, eventually, secondary osteoarthritis. However, many patients with DDH become symptomatic before the severe degenerative changes of the hip because of abnormal hip biomechanics, mild hip instability, impingement, or associated intra-articular pathology. Early diagnosis and appropriate treatment for DDH are of the utmost importance. With the modification of techniques like pelvic osteotomy and capsular arthroplasty, and the introduction of intracapsular procedures such as arthroscopy and femoral head-neck junction osteochondroplasty, many young patients with symptomatic hip dysplasia may benefit from joint preservation procedures. We review the current development of these concepts and the associated surgical techniques.

Keywords Hip · Dyslpasia · Joint preservation · Reconstruction

Introduction

Developmental dysplasia of the hip (DDH) remains a common cause of secondary osteoarthritis of the hip and may be a primary cause of disability in young adults. If appropriate measures are not taken, hip dysplasia leads to increasing stress loading of the acetabular rim and secondary hip osteoarthritis [1, 2]. Although hip osteoarthritis could be treated with total hip arthroplasty (THA), there are numerous reports about young patients who underwent THA presenting with a higher prevalence of dislocation, aseptic loosening, wear of the polyethylene, and revision rates [3–5]. The aim of orthopedic management, therefore, is to identify dysplasia at the earliest possible time and to choose appropriate joint preservation methods to normalize the hip. Proper surgical treatment options may improve their symptoms, reduce or delay degenerative changes, and avoid the potential problems associated with hip replacement in the young. Joint preservation in young patients with DDH is a technically demanding procedure. In this paper, we present a variety of joint-preserving surgical techniques in dysplastic hips, their advantages and drawbacks, ending with the author's treatment methods of choice.

Pathology

DDH often shares common anatomic abnormalities. The true acetabulum is typically shallow, lateralized, anteverted, and the anterior and medial wall are soft with poor bone stock. The coverage is usually deficient anteriorly, laterally, and superiorly. However, recent studies on larger populations with hip dysplasia have shown that the incidence of acetabular retroversion was up to 35 %, indicating anterior overcoverage [6]. The femoral head is elliptic, which causes incongruity of the hip joint [7], the decreased epiphyseal extends to the femoral neck [8], the neck has excessive anteversion and may be short, the neck-shaft angle is increased, the femoral head-neck offset is decreased, the greater trochanter is displaced posteriorly, and the femoral canal is narrow. As these bony changes develop, the soft tissues also become abnormal. Proximal migration of the femoral head accompanies with soft-tissue changes such as transverse orientation of the abductor muscles, capsular thickening, psoas tendon hypertrophy, and

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shortening of the hamstring, adductor, and rectus femoris muscles [9]. The femoral nerve exits the pelvis more laterally and superiorly, and the sciatic nerve becomes shortened over time.

All of mentioned pathological processes in dysplastic hip anatomy lead to apparently decreased contact area between the femoral head and acetabulum and to lateralization of the center of hip rotation, which can induce quicker deterioration of cartilage and bone tissue. Ultimately, patients with DDH suffer from earlier osteoarthritis of the hip joint.

Diagnosis

Typically, patients with DDH become symptomatic between their second and fifth decades of life. Groin pain is exacerbated with high-stress activity or prolonged standing, and lateral hip pain may be induced by crossing the affected leg over and stretching the hip abductors. Labral tears or chondral lesions may present with locking, catching, or giving way [9]. Hip ranges of motion are not generally decreased unless the presence of severe subluxation or secondary osteoarthritis [10]. Some special physical examination may help illustrate the nature of the hip pathology, in particular assessment of instability of the hip. The anterior impingement test may become positive with injury to the labrum or impingement of the femoral head-neck junction against the anterior acetabulum. The apprehension test can be positive with inadequate anterior coverage or hip instability. The Trendelenburg test is a special manoeuvre that is indicative of weakness of the hip abductor.

The radiographic diagnosis of hip dysplasia in the young adult is primarily based on the detection of deficient coverage of the femoral head by the acetabulum. Several plain radiographic views can be used, including standing AP pelvis, false profile and the frog-leg lateral and so on. The most commonly used measurements of DDH are a lateral-enter-edge angle of Wiberg, vertical-center-edge angle, Tönnis angle, and femoral head-neck-shaft angle (Table 1). Nözli et al. [11] reported the abnormality of the fovea capitis femoris, also referred to as “fovea alta”, as a potential radiographic characteristic for the dysplastic hip in adult. The delta angle (Table 1) is formed by drawing lines extending from medial edge of sourcil and superior edge of fovea capitis to the center the of femoral head. A normal hip has a delta angle greater than 10° and a delta angle in DDH is less than 10°.

Computed tomography images can provide morphologic analysis of acetabular deficiencies by measuring the anterior acetabular sector angle (AASA), the posterior acetabular sector angle (PASA), and the horizontal acetabular sector angle (HASA) [12]. It indicates a dysplastic hip if the AASA is less than 50°, the PASA less than 90° and the HASA less than 140° [13]. Magnetic resonance imaging (MRI) is useful for the assessment of symptomatic hips with a labral tear or chondral lesions that show no signs of structural abnormality on radiographs. Hip arthroscopy should be reserved for hips that have minimal radiographic abnormalities but in which intra-articular pathology is suspected [9].

Classifications

For a classification system to be useful, it should accurately assess the underlying pathological anatomy and compare the result of different methods of treatment. It should also be simple to plan and prepare operation for the orthopedic surgeon based on the grade of dysplasia. The classification systems described by Crowe et al. [14] and Hartofilakidis et al. [15] are most widely accepted to categorize the degree of dysplasia. Both of these two classification systems can be used for clinical practice or research purpose from different perspectives: Crowe et al. is quantitative and Hartofilakidis et al. is qualitative [16].

The Crowe classification is based on the extent of subluxation, which is the ratio between the distance of proximal migration of the femoral head and the vertical diameter of the un-deformed femoral head. The distance of proximal migration is calculated on an anteroposterior pelvis radiography by measuring the vertical distance between the inferior head-neck junction and the inter-tear-drop line. The predicted vertical diameter of the femoral head is equivalent to 20 % of the pelvic height when the femoral head is deformed [14]. DDH in adults could then be classified with four types of dislocation: Type I, <50 % subluxation or <0.10 of pelvic height; Type II, 50–75 % subluxation or 0.10–0.15 of pelvic height; Type III, 75–100 % subluxation or 0.16–0.20 of pelvic height; Type IV, >100 % subluxation or >0.20 of pelvic height (Table 2). Nevertheless, this system fails to define the acetabular abnormality which is helpful in determining the method of acetabular reconstruction during the THA for DDH.

Based upon the relationship between the femoral head and acetabulum, and the connection between true and false acetabulum, the classification system of Hartofilakidis et al. [15] divides DDH into three categories: dysplasia, low dislocation, and high dislocation (Table 3). Hartofilakidis et al. [17] additionally developed the classification system in 2008 by adding subtypes according to the relationship of the true and false acetabulum in type B and the presence and absence of a false acetabulum in type C (Table 4). The goal of the refinement of classification is to identify differences in treatment options and complications associated with the subtypes, which assists the surgeon in choosing the most appropriate solution to a problem.

Treatment options

Despite the development of modern bearing surfaces, THA should still be discouraged in young patients. With the

Table 1 Radiographic measurements of developmental dysplasia of the hip

Measurement	Description	Normal vs abnormal values
Lateral-centre-edge angle	Angle between vertical line through femoral head centre and line tangential to lateral margin of acetabulum	Normal>25° Borderline dysplasia=20–25° Dysplasia<20°
Vertical-centre-anterior margin angle	Angle between vertical line through femoral head centre and anterior margin of acetabulum	Normal>25° Borderline dysplasia=20–25° Dysplasia<20°
Tonnis angle	Angle between horizontal line at level of medial edge of sourcil and line tangential to medial and lateral edges of sourcil	Normal≤13° Dysplastic>13°
Femoral head-neck-shaft angle	Angle between line through femoral head centre along axis of femoral neck and intersecting line drawn along femoral shaft axis	Normal 120–135° Coxa valga>135° Coxa vara<120°
Delta angle	Angle between lines drawn through medial edge of sourcil and superior edge of fovea capitis through femoral head centre	Normal>10° Fovea alta≤10°

modification of techniques like pelvic osteotomy and capsular arthroplasty, and the introduction of intracapsular procedures such as arthroscopy, femoral head-neck junction osteochondroplasty and femoral head reduction osteotomy, many young patients with symptomatic DDH, in the absence of severe osteoarthritis, may benefit from joint preservation procedures [18–23].

Hip arthroscopy

Hip arthroscopy provides an opportunity to address the intra-articular pathology associated with loose bodies, labral tears, chondral damages, and synovial disease. However, a primary limitation of arthroscopic surgery is the fact that it does not correct the osseous abnormality which is the underlying cause of the mechanical symptoms in DDH. Parvizi et al. [24] described their outcomes in 34 patients with DDH treated with hip arthroscopy alone for intra-articular pathology. They observed that 44 % of their study population subsequently required additional open procedures. They raised a cautionary note that patients with DDH might not benefit from isolated hip arthroscopy.

Although isolated hip arthroscopy has limited applicability in the treatment of hip dysplasia, it is used as adjuvant treatment when combined with bony reconstructive procedures [25–27]. The labral tears, cartilage flaps, and chondromalacia can be visually inspected by hip arthroscopy prior to osteotomy. If the intra-articular pathology is more severe than predicted preoperatively, the extra-articular osteotomy may be of little value. Kim et al. [22] published their good results of hip arthroscopy in conjunction with periacetabular osteotomy in patients with symptomatic DDH in the medium term. They found that 88 % of their study objects had labral lesions. All patients with labral lesions underwent arthroscopic labral debridement. At an average of 74 months follow-up, the mean Harris hip score (HHS) improved from 72.4 to 94, as did all the radiological parameters. Lian et al. [28] reported similar outcomes of rotational acetabular osteotomy combined with debridement under an arthroscope in the treatment of DDH. Of 24 patients, the HHS was improved from 79.4±9.8 to 95.1 ±8.6, and the visual analogue scale (VAS) score was improved from 5.1±0.8 to 1.1±0.6 at a mean of 4.5 years' follow-up. They observed that the osteoarthritis scores according to Tönnis in all patients were maintained, even in five hips that were improved.

Table 2 Crowe classification for DDH in adults

Type	Description
I	<50 % subluxation or <0.10 of pelvic height
II	50–75 % subluxation or 0.10–0.15 of pelvic height
III	75–100 % subluxation or 0.16–0.20 of pelvic height
IV	>100 % subluxation or >0.20 of pelvic height

Periacetabular osteotomy

The Bernese periacetabular osteotomy (PAO) developed by Ganz et al. in 1983 [18] is the preferred reconstructive osteotomy due to its balance between minimal exposure, complications and ability to provide optimal correction [29]. PAO is performed through an abductor-sparing modification of the Smith-Petersen anterior iliofemoral approach, including an osteotomy of the anterior superior iliac spine. The surgical procedure of PAO consists of four osteotomies: incomplete ischiatic osteotomy; complete osteotomy of the superior pubic ramus; supra-acetabular iliac osteotomy; and retro-acetabular iliac osteotomy, joining cut number one (Fig. 1). The mobilized acetabular fragment is then reoriented in optimal position on the basis of the preoperative radiographs and temporarily

Table 3 Hartofilakidis classification for DDH in adults

Type	Description	Acetabular anatomy during surgery
Dysplastic hip	The femoral head is contained within the original acetabulum despite the degree of subluxation	Segmental deficiency of the superior wall Secondary shallowness due to fossa-covering osteophyte
Low dislocation	The femoral head articulates with a false acetabulum that partially covers the true acetabulum to a varying degree	Complete absence of the superior wall Anterior and posterior segmental deficiency Narrow opening and inadequate depth of the true acetabulum
High dislocation	The femoral head is completely out of the true acetabulum and migrated superiorly and posteriorly to a varying degree	Segmental deficiency of the entire with narrow opening Inadequate depth Excessive anteversion Abnormal distribution of bone stock, mainly located superoposteriorly in relation to the true acetabulum

fixed with smooth Kirschner wires. There are several parameters to assess intraoperatively with fluoroscopy [30]: the sourcil should be horizontal but not negative [31]; the centre edge angle should be between 25 and 35°, with at least 80 % lateral coverage of the femoral head; the hip centre should be slightly medialized to improve joint reactive forces; the anterior and posterior walls should meet at the lateral edge of the joint to avoid postoperative femoroacetabular impingement (FAI). The acetabular fragment is then definitively fixed with three or four cortical 4.5-mm screws when a satisfactory correction has been achieved. Following surgical correction, hip range of motion in flexion and internal and external rotation is evaluated and any potential impingement is addressed.

The most accepted indication for PAO is a patient less than 40 years of age who presents with mild to moderate symptomatic dysplasia, good to excellent congruence between the acetabulum and femoral head [32], a Tönnis grade of 0 or 1 [33] (Table 5), and is not obese (BMI<30 kg/m^2). Conversely, with

Table 4 The modification of Hartofilakidis classification for DDH in adults

Type	Subtpyes	Description
Dysplastic hip	A	
Low dislocation	B1	The false acetabulum covers more than 50 % of the true acetabulum; resembles dysplasia
	B2	The false acetabulum covers less than 50 % of the true acetabulum; resembles high dislocation
High dislocation	C1	The femoral head articulates with a false acetabulum
	C2	No false acetabulum; the femoral head is free-floating within the gluteal musculature

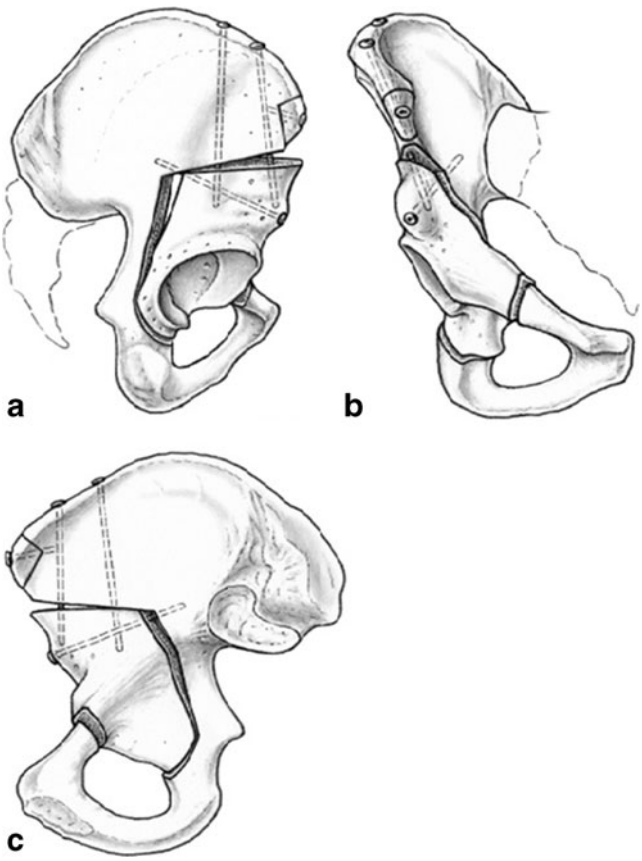

Fig. 1 The Bernese PAO is performed through a modified Smith-Petersen approach, including an osteotomy of the anterior superior iliac spine to dissect the inguinal ligament and the adjacent muscles. **a** With four periacetabular osteotomies and a controlled fracture, the acetabulum is completely mobilized from the innominate bone. **b** For fixation of the reoriented fragment, three cortical screws are used. **c** The posterior column of the true pelvis remains intact maintaining stability through an intact continuity of the pelvic ring. (Reproduced, with permission, from Pogliacomi et al. [74])

Table 5 Tönnis classification of osteoarthritis by radiographic changes

Grade	Description
0	No signs of osteoarthritis
1	Mild: increased sclerosis, slight narrowing of the joint space, no or slight loss of head sphericity
2	Moderate: small cysts, moderate narrowing of the joint space, moderate loss of head sphericity
3	Severe: large cysts, severe narrowing or obliteration of the joints pace, severe deformity of the head

joint space narrowing, a supra-acetabular cyst visible on X-ray or MRI, or incongruence between the femoral head and acetabulum, patients >40 years of age are better candidates for THA.

The advantages of PAO are multi-faceted compared with other acetabular re-orientation osteotomies. Via only one incision, it is performed with a series of reproducible hexagonal cuts around the acetabulum leaving the posterior column of the pelvis intact, which maintains the stability of the pelvis and allows early weightbearing post-operatively. The abductors can be preserved owing to an alteration of the osteotomy cuts made from the inner aspect of the pelvis. In particular, the fragment without attachment to the scarospinous ligaments can be orientated medially, laterally and anteriorly so that the correction of deformity can be accomplished [34]. Additionally, future vaginal delivery is still safe for women of childbearing age because there is no change in the dimensions of the true pelvis when osteotomy is finished [35, 36]. Finally, a capsulotomy can be carried out through the same approach to detect the labrum and articular cartilage damage without compromising the blood supply to the acetabulum [37]. Major complications including symptomatic heterotopic ossification, wound hematomas, nerve palsies, loss of the fixation, and malreductions were common and occurred in 6–37 % of cases [38]. This relatively high complication rates may reflect the complexity of the procedure and the surgeon learning curve effect.

PAO is a successful procedure in pain relief and improvement of hip functional scores in patients with mild to moderate symptomatic hip dysplasia. Clinical follow-up with similar improvements in hip functional scores, preventions in radiological progression of arthritis and survival rate have been reported in many papers [39–52]. Matheney et al. [45] showed a survivorship of 76 % at an average of nine years in 157 patients (189 hips) treated with PAO, with an average Western Ontario and McMaster Universities pain score of 2.4 of 20. Steppacher et al. [43] published a mean 20-year follow-up of PAO in 58 patients (68 hips) showing a survivorship, defined as not yet requiring THA or arthrodesis, of 93.2 % at 5 years, 87.6 % at ten years and 60.5 % at 20 years. Despite all that, none have shown significant improvement in the range of hip motion.

Femoral head-neck junction osteochondroplasty combined with PAO

Cam-type FAI presents with an aspherical femoral head-neck junction or a reduction in the head-neck offset. A cam effect occurs during flexion and internal rotation of the hip. The aspherical part of the femoral head is wedged into the acetabulum, which in turn induces damage to the acetabular labrum and adjacent cartilage [21, 53]. The alpha-angle, described by Nötzli et al. [54], has been used to assess the asphericity of the femoral head-neck junction on the frog-leg lateral images. The average value of the alpha-angle in asymptomatic hips is 42°. An alpha-angle of greater than 50 to 55° is considered a cam deformity of the femoral head-neck junction. The femoral head-neck offset ratio, defined as the ratio between the head-neck offset distance and the femoral head diameter, is calculated from the cross-table lateral view of the hip in 10° of internal rotation. Beaulé et al. [55] concluded that a value of the femoral head-neck offset ratio less than 0.15 had a 95 % positive predictive value of diagnosing FAI.

Despite overall good results of symptomatic DDH in intermediate and long-term follow-up, there is increasing evidence that residual FAI, which is a cause of ongoing clinical symptoms, can induce cartilage damage and labral tears [56]. Ida et al. [57] revealed that 40 % of patients with dysplasitic hip also had radiographic evidence of cam-type proximal femoral deformity. Steppacher et al. [43] reported a survival rate of 60.5 % at 20 years and identified six factors associated with poor outcomes after PAO: age, pre-operative Merle d'Aubigne and Postel score, positive anterior impingement test, pre-operative limp, osteoarthrosis grade, and the post-operative extrusion index. Of those six factors, a positive post-operative impingement sign showed the highest hazard ratio. Based on these observations, some surgeons suggested arthrotomy and femoral head-neck osteochondroplasty for patients with DDH as a routine procedure to reduce the risk of FAI when a femoral head-neck malformation was present and/or when a test of FAI was positive [58, 59].

Following the re-orientation of the acetabulum, an arthrotomy is performed when a labral tear and/or FAI are suspected. The labral tear is treated by resection of the acetabular rim or reattachment of the labrum with suture anchors, if possible [60]. Then the aspherical portion of the femoral head-neck junction is removed using a burr until internal rotation of 20–25° is available at 90° hip flexion. A transparent template is utilized to check whether the contour of the femoral head becomes a spherical shape (Fig. 2). The amount of the head-neck junction osteochondroplasty is determined in accordance with direct visualization, dynamic examination, and fluoroscopy.

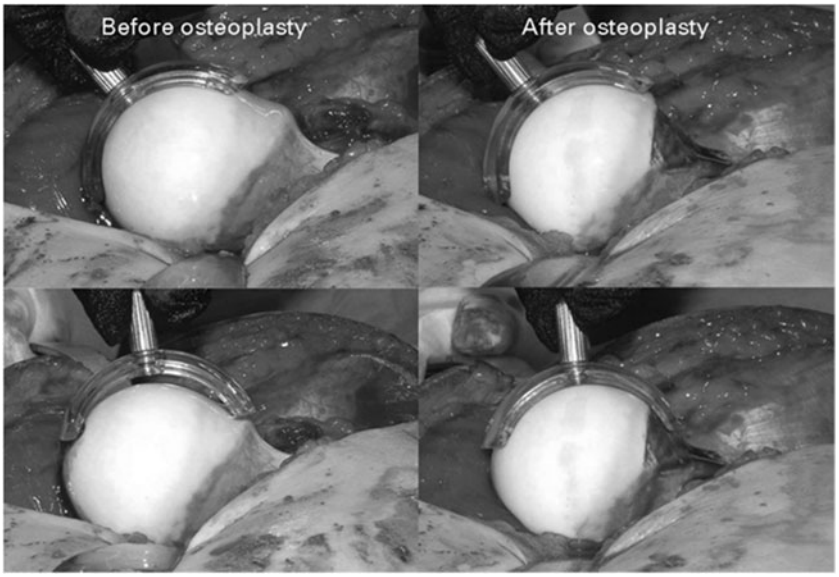

Fig. 2 Intraoperative photographs showing the use of a transparent template to help in the moulding of a non-spherical shape into a spherical shape. (Reproduced, with permission, from Leunig and Ganz [75])

Recently, more and more papers associated with femoral head-neck junction osteochondroplasty combined with PAO for DDH are reported. Albers et al. [23] found a superior survivorship rate of 90 % after PAO at the ten year follow-up if the acetabulum was properly corrected and a femoral head-neck junction osteochondroplasty was accomplished by an arthrotomy. Therefore, they suggested that an optimal acetabular re-orientation with correction of the femoral head-neck offset could improve long-term survival and decelerate osteoarthritis progression after PAO. Nassif et al. [56] reported the results of femoral head-neck junction osteochondroplasty performed in conjunction with PAO for the treatment of symptomatic hip dysplasia associated with femoral head-neck junction deformity. This combined procedure provided reliable correction of associated femoral head-neck malformations and reduced the re-operation rate owing to FAI. Nevertheless, they have not found superior clinical results with respect to an adjunctive head-neck junction osteochondroplasty. The clinical benefit of correcting FAI is necessary to balance with the additional potential complications such as adhesion, capsular scarring, heterotopic ossification, femoral neck fracture, and osteonecrosis of the femoral head.

Varus intertrochanteric osteotomy

Varus intertrochanteric osteotomy (ITO) should be taken into account when the femur has a significant deformity, including high neck-shaft angle and an ipsilateral longer leg or when a pelvic osteotomy does not provide adequate correction. With experience in performing PAO, we have now come to rely less upon the varus ITO to achieve lateral coverage. Occasionally, deformities on both sides of the hip joint are encountered in DDH, then PAO should be performed in conjunction with proximal femoral osteotomy such as varus ITO [61].

Clinical results of varus ITO are controversial in many papers. Ansaria et al. [62] reported a retrospective study that supported the use of isolated varus proximal femoral osteotomy as a treatment option for young adults with DDH and particularly in patients with ipsilateral longer leg, even when early degenerative change was present. Koulouvaris et al. [63] reported the long-term results in 52 patients who underwent the varus ITO were very encouraging, which showed survival probability was 93 % at nine years. However, Ito et al. [64] reported the results of 55 varus ITOs in 46 patients with hip dysplasia after the mean 17 years of follow-up. They described only 42 % of the results to be acceptable in patients with a greater degree of dysplasia and advanced osteoarthritic changes. They suggested that the varus ITO might not be carried out for them. Seen from the literature, the prerequisite for a good outcome of varus ITO is the strict indication, such as: (1) younger age; (2) a Tönnis grade of 0 or 1; (3) spherical femoral head, unilateral coxa valga; (4) good congruency in the abducted position, a minimal abduction of 15°; (5) major deformity on the femoral side.

Varus ITO has several drawbacks, including shortening of the leg, a Trendelenburg gait, nonunion of the osteotomy, loss of fixation, and avascular necrosis of the femoral head. Hemorrhage, haematoma, infection, and nerve palsy due to technique are quite rare now. Reassuringly, Boos et al. [65] and Haverkamp et al. [66] published the presence of a previous ITO did not affect the clinical and radiological outcomes of future THA.

Capsular arthroplasty

Despite increasing use of ultrasound as an early screening method for the detection of DDH in early infancy, high dislocation of the hip is found occasionally [67–69]. It is extremely

difficult to deal with such patients because of the bone and soft tissue deformities. The deformities of the proximal femur are varied in high dislocation of the hip, including: the femoral head is elliptic and bigger; the femoral neck has excessive anteversion and may be short; the neck-shaft angle is increased; the greater trochanter is displaced posteriorly. The acetabulum is almost developmental with a narrow opening, which is unsuitable to treat with PAO. Proximal migration of the femoral head accompanies with soft-tissue changes such as transverse orientation of the abductor muscles, capsular thickening, psoas tendon hypertrophy, and shortening of the hamstring, adductor, and rectus femoris muscles [9]. The sciatic nerve becomes shortened and therefore is prone to injury with lengthening of >4 cm when the hip is reconstructed [70]. Given these reasons, treatment of young people with DDH with the use of joint preservation is extremely challenging.

The capsular arthroplasty is a useful but abandoned procedure for young patients with DDH because of relatively high rates of osteonecrosis of the femoral head, joint stiffness, and redislocation [71, 72]. However, Ganz et al. [19] supported the revival of joint preservation with a modified capsular arthroplasty if the function could be restored and complication rates were reduced. Via a surgical hip dislocation (SHD) [20], a modified capsular arthroplasty was performed in a lateral decubitus position (Fig. 3). The key part of this operation was the correct performance of the capsulotomy (Fig. 4). The incision of the capsule was executed as close as possible to the osseous acetabular rim in a T-shaped manner to preserve adequate capsular tissue for later wrapping around the femoral head. Excision of fatty tissue from the fossa acetabuli ensured optimal orientation of the reamer. Hip arthroplasty reamers were directed toward the notch to ream a new acetabulum. Then, a trial reduction without wrapping the head in the capsule was attempted. If the reduction of the femoral head was impossible or a sciatic nerve became tensive with the knee flexed, a transverse subtrochanteric osteotomy was performed. The amount of shortening was equal to the distance of the bone overlap at the subtrochanteric osteotomy when the femoral head covered with capsule was reduced and the knee fully extended. Next, derotation was executed to get a femoral neck anteversion of 15–20°, and the fracture was fixed with the plate and screws. In addition, a femoral head reduction osteotomy [73] was determined when the femoral head with the capsular covering was larger than the excavated acetabulum. If the femoral neck was short, a relative lengthening of the neck [73] was done to decrease the risk of FAI.

This imaginative method of SHD to reduce the rate of avascular necrosis of the femoral head [20] may improve the outcome of capsular arthroplasty. Ganz et al. [19] retrospectively reported the results of nine patients (age range, 13–25 years) who underwent such procedures between 1977 and 2010 with the mean 7.5 years follow-up. The mean HHS was 84 (n=7) at last follow-up and one patient had

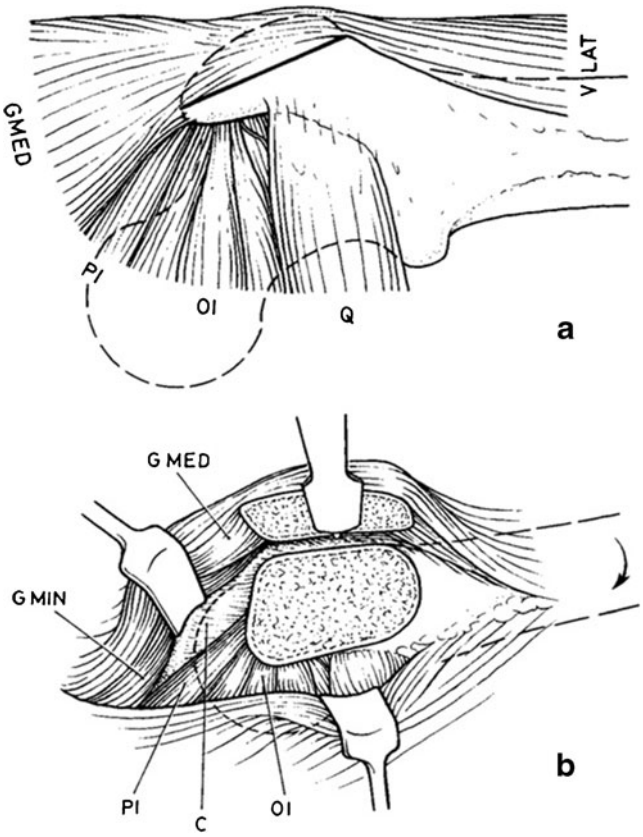

Fig. 3 Diagrams showing surgical hip dislocation. **a** The *line* of trochanteric osteotomy for the trochanteric flip. Proximally, the osteotomy exits just anterior to the most posterior insertion of gluteus medius. Distally, the entire origin of vastus lateralis remains on the trochanteric fragment. **b** In slight flexion and external rotation of the femur (*arrow*), the trochanteric fragment is flipped over anteriorly. The interval between gluteus minimus and the tendon of piriformis is then developed and gluteus minimus retracted superiorly to expose the capsule (*GMED* gluteus medius, *PI* piriformis, *OI* obturator internus, *Q* quadratus femoris, *VLAT* vastus lateralis, *GMIN* gluteus minimus, *C* capsule). (Reproduced, with permission, from Ganz et al [20])

THA after 27 years. Therefore, they suggested capsular arthroplasty performed with a SHD and other proper adjunctive procedures such as a subtrochanteric shortening or derotation osteotomy, a relative neck lengthening, a femoral head reduction osteotomy and roof augmentation was a useful procedure for young patients with dislocated hips. It may delay THA.

Summary

The treatment of hip dysplasia in young adults is based on the degree of hip dysplasia and the amount of accompanying arthritis. The mild hip dysplasia with intra-articular pathology, like labral tear or chondral lesion detected by MRI or physical examination, can undergo arthroscopy in conjunction with PAO. Otherwise, PAO should be performed alone for mild

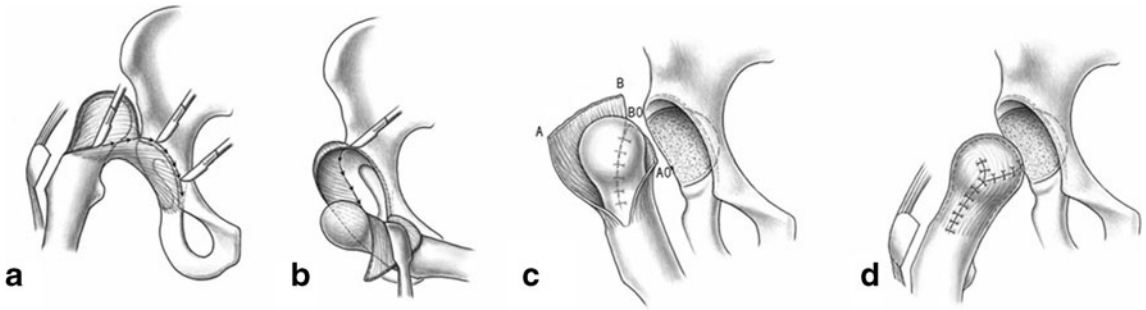

Fig. 4 Diagrams illustrate capsular incision. **a** The first incision of the capsule runs from the anterosuperior edge of the trochanteric osteotomy to the most superior point of the anterior rim. The incision is extended as close as possible to the anterior osseous rim down to the transverse ligament. With traction on the leg, the correct level of superior capsulotomy can be determined. **b** To inspect the joint, the elongated round ligament is excised. The femoral head is dislocated from the capsular cavity and held distally with the use of a Hohmann retractor hooked around the acetabular notch. Posterior capsulotomy can be executed from outside or inside. **c** After all capsular connections with the acetabular rim are sectioned, the leg is extended and the neck is lifted anteriorly using a bone hook. This allows approximation of the posterior capsular margins B to B0 and suture from caudad to cephalad. It is followed by the anterior suture A to A0. **d** Closure of the capsule over the head must be executed firmly but without tissue overlapping. (Reproduced, with permission, from Ganz et al. [19])

dysplasia. Acetabular dysplasia with apparent coxa valgus when good congruency can be observed between the femoral head and acetabulum in the abducted position can undergo varus ITO based on PAO. Those patients coupled with cam-type FAI can undergo femoral head-neck junction osteochondroplasty and PAO. High dislocation of DDH can be treated with capsular arthroplasty combined with other proper adjunctive procedures, such as a subtrochanteric shortening or derotation osteotomy, a relative neck lengthening, a femoral head reduction osteotomy to postpone THA.

Conflict of interest The authors declare that they have no conflicts of interest.

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